THE

AËRONAUTICAL JOURNAL.

(FOUNDED 1897 in succession to the ANNUAL REPORTS).

THE ORGAN OF THE ROYAL AËRONAUTICAL SOCIETY.

Published Monthly at the Offices of the Society, at 7, Albemarle Street, Piccadilly, London, W.1.
Telephone: "Gerrard 7373." Telegraphic Address: "Didaskalos, Piccy, London."
Subscriptions per annum, post free, £1 10s.; single numbers, 2s. 9d.

Edited for the Council by W. BARNARD FARADAY, LL.B., F.S.S., Barrister-at-Law.

All communications should be addressed to the Editor.

No. 108. DECEMBER, 1919. VOL. XXIII.

Notices of the Royal Aëronautical Society.

The Library.

After January 1st the Society's Library will be open for the use of Students and others during the winter months on Saturday afternoons from 2.0 to 5.0 p.m.

The Secretaryship.

Lieutenant-Colonel W. Lockwood Marsh has been appointed Secretary of the Society as from January 1st, 1920.

Obituary.

We regret to record the death, on December 5th, of Mr. Frank Gregory, an Associate Member of the Society. He joined the Society in March, 1918, and is regretted by his many friends in the Society.

The Syllabus.

The Lectures for 1920 will be announced in the January number. A full and interesting series of meetings has been arranged. The opening meeting is fixed for January 8th. As in previous years, this will be the occasion for a "Juvenile" lecture at 3.0 in the afternoon. As a large demand for tickets is expected, members will greatly assist the staff by making application at once. The lecture is open to all members and their families and friends.

Subscriptions.

Members of the Society are reminded that their subscriptions fall due on January 1st, 1920. They will greatly assist the work of the Society by sending the amount of their subscription early in the New Year.

The Journal.

Owing to the very heavy increase in the cost of printing, the Council, with very great regret, are compelled to increase the price to non-members to 3s. 6d. per copy, or 45s. per annum post free. Members of the Society will continue to receive copies as before.

THE STATIC HEAD TURN INDICATOR FOR AEROPLANES.

BY SIR HORACE DARWIN, K.B.E., F.R.S.

An instrument to indicate whether, under all conditions, the path of the aeroplane is a straight line or whether it is turning to the right or left, is much required. It is well known that when flying in a cloud or at night, and no fixed object is visible, even the most experienced pilot may, without realising it, be flying on a sharp curve. If, however, the angle of banking is great the muscular reaction of his body will have to be increased to counteract the increased force acting on it. This will tell him that his course is not straight, but there is nothing to show whether he is on a right-hand or left-hand turn. If he tries to straighten his course he is just as likely to increase the curvature as to straighten out. If he observes his compass he will probably find that it is swinging so much that it will tell him something is wrong, but give no guide to what he should do.

A turn indicator enables a straight compass course to be kept when flying in clouds or at night, and this is valuable for long-distance flights. But straight flying is always important. If the clouds are low and the aeroplane leaves their lower surface when on a sharp turn, there may not be sufficient time to allow the machine to be put into a safe position for landing before the ground is reached.

The late Captain Lucas, D.Sc., F.R.S., proved that when flying in a northerly direction the compass turned with the aeroplane, and when flying in a southerly direction the opposite took place. Before he investigated the subject at the Royal Aircraft Establishment all that was known was that the compass became unreliable in cloud flying; he found what the facts were; discovered the cause of the behaviour of the compass; and designed and made a compass which was a very great improvement on the compass then in use, although it did not completely overcome the difficulty. This scientific achievement was of the greatest value to the flying service. It was when doing such work as this that he was killed, and the country lost a brilliant scientific man.

In June, 1912, a memorandum by Mr. C. C. Mason and myself was submitted to the Advisory Committee for Aeronautics. In it the principle of the Static Head Turn Indicator was explained. At a later date Dr. Lucas tried some experiments with the manometer supplied by me, a very different one from that now made by the British Wright Co. This manometer was crude and bad in principle, and broke down after a short trial, but showed some promise. The experiments were not continued owing to press of other work, and because I think even he did not then realise the value of a satisfactory turn indicator, and I certainly did not.

The object in view at that time was to obtain the true vertical for bomb dropping. Major Dobson tried some interesting experiments at Upavon with very simple apparatus. Later I made an elaborate instrument which was probably too difficult to manipulate.

There have been many attempts to make instruments which would show the true vertical when flying in a circle. If a pendulum hanging from a support on an aeroplane would always point in the true vertical direction it would be easy to make an instrument which would show whether the wings were level. But it is well known that this is not the case; on a truly banked turn the pendulum will remain at right angles to the plane of the wings, and the pendulum will only show whether the aeroplane is under or over banked. Many inventors have suggested pendulums, or their equivalents, such as a level, or bubbles rising through a vessel containing a liquid, or a flame which points vertically upwards. Very few

of the inventors of these instruments realised the fundamental difficulty, and those few who did, failed to overcome it.

Another possible method is to make use of the fact that on a turn the apparent attraction of gravity is increased. The index of an ordinary spring balance supporting a weight would move when on a banked turn, and show a greater weight than when flying straight. In this case a left and right turn would have the same effect. Also the indication would be very small even for turns of large radius. The vertical acceleration, especially on bumpy days, would have a far greater effect than even sharp turns.

It has also been proposed to measure the banking angle by an electrometer giving the difference of the electro-static potential at the wing tips. This method was, however, not found to be a success.

Successful turn indicators using gyroscopes have been made.

We will now describe the Static Head Turn Indicator.* In conjunction with a good aeroplane compass and a cross level, a true compass course can be kept in clouds or at night. The success of this instrument is due to the large amount of experimental work done at Orfordness and at the Royal Aircraft Establishment, and to the design of the Ogilvie Pressure Gauge manufactured by the British Wright Company. Unless a pressure gauge as good and as sensitive as this instrument had been designed, the turn indicator would not have been a success.

A great number of experiments had to be tried in order to determine the best position for fixing the static heads, on the relative advantages of fixed and swivelling static heads, and on the effect of side-slip.

A sensitive differential manometer is fixed on the instrument board, and the Ogilvie Pressure Gauge is used for this purpose. The two openings from it are connected to two static heads, fixed to the wings as far apart as can conveniently be arranged, and in a position so that the air pressure at these points is influenced as little as possible by the wings or body of the aeroplane. The manometer will then indicate a difference of pressure when the aeroplane is turning. The hand will move in one direction for a turn to the right and in the other direction for a turn to the left.

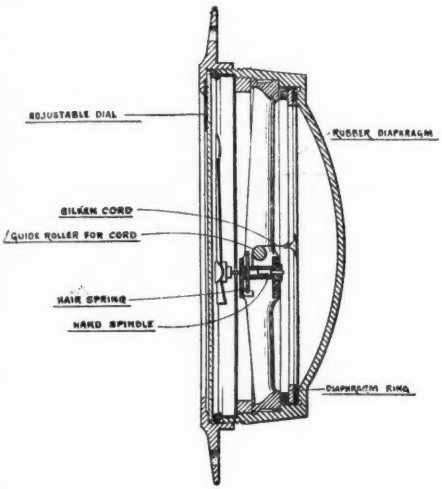
The pressure gauge was designed by the British Wright Company for use with the turn indicator, and is of the Ogilvie type. An extremely sensitive circular rubber diaphragm separates two chambers in the instrument. These chambers are connected, one to each static head, and the minute difference of pressures caused by the aeroplane turning deflects the diaphragm by a small amount. The deflection is communicated directly by a silk thread, without intermediate gear, to the indicating hand and moves it to the right or the left. The scale carrying the zero mark and divisions is adjustable by the pilot during flight by the use of one thumb, and he can easily set the scale in the correct position when flying on a straight course immediately after leaving the ground. This adjustment is most desirable, as it is found that the position of the hand when on a straight course does not correspond with absolute equality of pressure on the two sides of the diaphragm.

This inequality of pressure is because it is impossible to make both static heads absolutely similar, and also because the actual static pressures at the two positions where the static heads are fixed are not equal. No doubt if it were possible to fix the static heads at a great distance in front of the wings the amount of adjustment required would be greatly reduced. The adjustment required is seldom more than 10°.

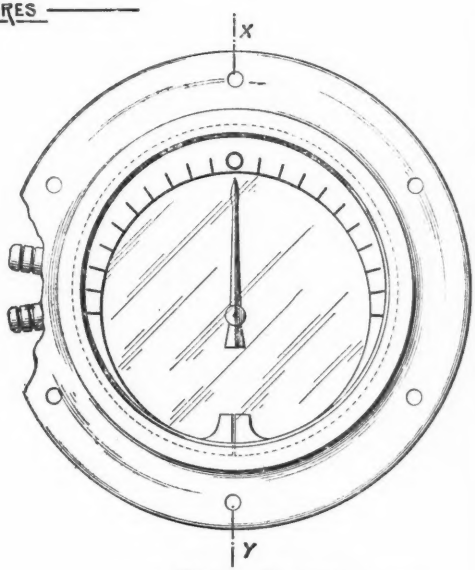
The air inside the static openings is very nearly the true air pressure outside

* Secret Patent (applied for March 20th, 1918) was taken out for this invention. The Patent No. 123,996 was published on April 10th, 1919. In the Service it is known as the "Aero Turn Indicator with Mark I. and Mark II. Static Heads."

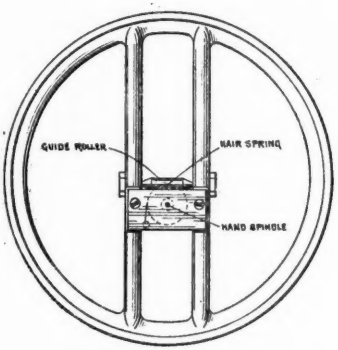
The Ogilvie Pressure Gauge adapted for indicating minute differences between two balanced pressures



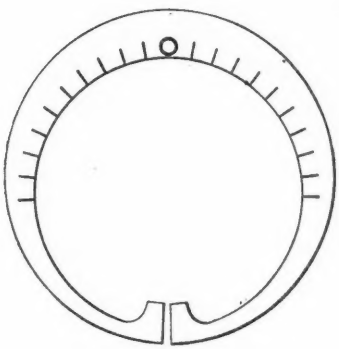
Section on line X-Y



Front Elevation



Bridge Frame



Adjustable Dial

FIG. 1.

in a well-designed static opening. The static heads used are the same in form as those used in the standard air-speed indicator. The tube moves through the air in the direction of its axis; the stream-line end of the tube disturbs the air as little as possible, and thus the air passes over the holes in the side of the tube at right angles to their direction. It had been found by experiment that the air pressure inside the tube is very nearly the true pressure outside, whatever the velocity of the tube may be.

Dr. H. Gadors, F.R.S., a great authority on birds, tells me that they breathe through their nostrils. It is an interesting fact that the nostrils of birds fulfil to some extent the conditions of a well-designed static opening; the nostrils are holes in the beak, and in flight the beak moves through the air point forwards. It is clear that this arrangement is advantageous to the bird. To ensure ease

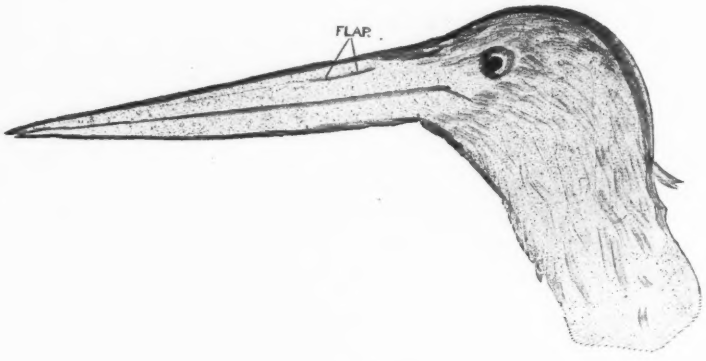


FIG. 2.

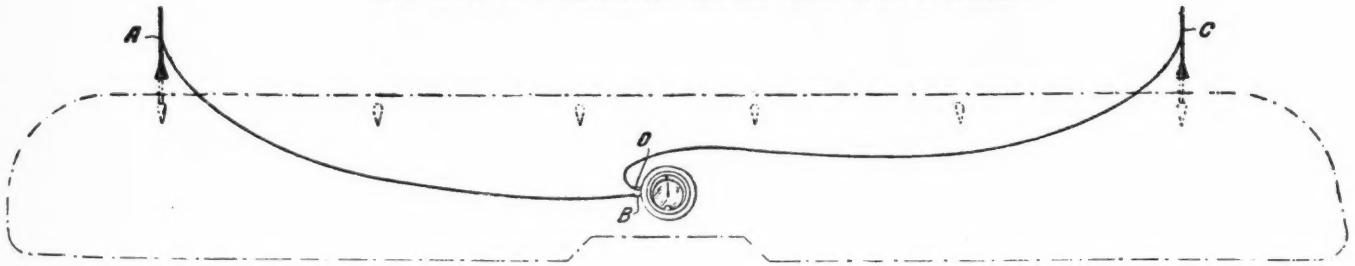
in breathing, the air inside the lungs should be at the same pressure as the air outside. I do not know whether men in aeroplanes find any difficulty in breathing when the head is in the wind. If they do, no doubt the difficulty could be reduced by breathing through properly constructed static openings.

Experiments were tried with fixed static heads, as it was hoped that the swivelling form was not necessary. They were fixed to the struts between the wings, but in this position side-slipping had a considerable effect; in some cases this was so great that the index of the pressure gauge showed a right-hand turn when a left-hand turn was taken. The fixed static heads were then placed in front and above the leading edge of the upper wing. In this position the results were much better, but the heads must be truly parallel. But it was found that they were liable to become accidentally displaced, and as this might easily happen without the pilot knowing it, the instrument would not then be trustworthy. When swivelling heads are used and placed in the standard position, the effect of side-slip is greatly reduced, and turns to the right or left are correctly indicated. To eliminate all effect of side-slip the static heads must be put inconveniently far from the wings.

The swivelling static heads are required to adjust their angle with the greatest freedom. They are carried by swivelling bearings allowing universal movement, and fixed to rigid standards. The air is always free to flow by way of a rubber tube which twists to accommodate the adjustment of the head to right and left, and bends to permit of inclination up and down. The static head, thus free to move in all directions, is maintained parallel to the direction of the wind

FIG. 3.

LAY OUT OF PRESSURE GAUGE AND STATIC HEADS.



A. Port static head.

B. Tube connecting port static head to gauge.

C. Starboard static head.

D. Tube connecting starboard static head to gauge.

by means of a conical vane. Its weight has no tendency to move it out of the true direction as it is carefully balanced about its swivelling bearings.

It was also found important to avoid sharp bends or constrictions in the tube, as otherwise the indication on the dial was sluggish. The air tube on the static head openings becoming blocked with ice is a possible cause of failure.

Some of the earlier experiments were made with venturi tubes instead of static openings at the ends of the air tube. This will reduce the air pressure at both the outer ends of the air tube, and it will reduce it most at the end which is moving fastest through the air. When flying in a circle, the outer wing tip is

FIG. 4.

moving faster than the inner wing tip, and the air in the air tube will be drawn outwards and this will cause a pressure on the manometer. This pressure will be in the same direction as the pressure caused by the centrifugal force, and the two pressures will be added together and the effect will be greater than when static heads are used. The result is that the pressure on the manometer is increased, and this is an advantage.

This arrangement was tried, but the readings on the manometer were found to be much more unsteady, and for this reason the instrument was less satisfactory than when static heads were used.

Major G. I. Taylor has investigated the question of gusts and eddies in the air. In a gust the static pressure as well as the velocity vary. When static heads are used the change of velocity has no effect on the air pressure in the air tube, and unsteadiness of the manometer readings is only caused by the variation in the pressure. With venturi tubes, both the variation of velocity and pressure will cause unsteadiness. It has been found that the fluctuations in static pressure due to gusts are of the order of $\rho u^2/2$ where u is the fluctuation of the velocity in the gust. The velocity of the gust may increase or diminish the velocity of the venturi tube through the air, depending on the direction of the gust; and

may even have opposite effects on the ends of the air tube, increasing the velocity at one end and diminishing it at the other.

If the velocity of the venturi tube through the air is v and a gust of velocity u meets it, then the velocity through the air becomes $v+u$. The reduction of pressure in a venturi tube is approximately proportional to the square of the velocity of the air. The reduction of pressure is $\frac{1}{2}\rho\left[(v+u)^2 - v^2\right]$ or ρvu as u is small compared to v. With a quick-flying aeroplane v is very large and the reduction of pressure will be by no means small even if the velocity of the gust is very small, and we should expect the pointer of the manometer to be unsteady.

It follows from the foregoing that we should expect this unsteadiness to be from 10 to 20 times as great with venturi tubes as with the static heads, and this has been verified by tests in the air.

Small differences of pressure have to be measured, and as venturi tubes are very sensitive to change of shape, it would also be very difficult to make them sufficiently alike.

It is found also that in actual practice a venturi tube gives an unsteady suction even in a uniform wind. This is probably caused by the flow of the air through the venturi tube becoming unstable at some velocities. Pitot tubes for this reason also, are better than venturi tubes.

A manometer has been made sufficiently sensitive to indicate turns of large radius, and as steadiness of the readings is of very great importance, it is far better to use static heads than venturi tubes.

In order to make the action clear, we will assume that the aeroplane is moving in a circle, that it is not banked, and that the air tube connecting the static heads is horizontal and points along a radius of the circle. The forces acting on the air in this tube are :—

1. Gravity acting vertically downwards. As the tube is horizontal this will cause no difference of pressure at the manometer nor cause any tendency of the air to move along the tube.

2. The atmospheric pressure at the static heads. As the tube is horizontal the pressures at the ends of the tube are equal and in opposite directions, and no effect is produced on the manometer.

3. The pressure of the inner surface of the tube against the air ; this clearly has no effect on the manometer.

4. Centrifugal force is the one remaining force which can cause a movement of the differential manometer. The air will tend to move along the tube in an outward direction and can only be prevented from so doing by a difference of pressure on the two sides of the diaphragm in the manometer. It is this difference of pressure which is indicated on the manometer and shows a right or left-hand turn.

All turns, however, are banked and this assumption is only made to make the action clear.

Let us now consider a banked turn and assume that the aeroplane is banked at the correct angle. By the correct angle is meant an angle which causes no side-slip ; that is, such an angle that the apparent direction of gravity (that is, the resultant of gravity and centrifugal force) is at right angles to the plane of the wings.

Again consider the forces acting on the air in the tube.

1. As the banking is at the correct angle, the resultant of gravity and centrifugal force acts at right angles to the direction of the tube and has no effect.

2. The pressure against the inside of the tube clearly has no effect.

3. The atmospheric pressure at the two static heads is not equal; as the aeroplane is banked, the outer end is higher up and at a place where the air is at a less pressure. The differential manometer will show this difference of pressure.

Or we can consider this last case differently. The forces acting on the air in the tube are :—

1. Gravity acting on the air in the tube. As the tube is banked this will tend to make the air flow inwards.

2. Atmospheric pressure at the static heads. As the pressure at the outer end is less than at the inner end these pressures will tend to make the air flow outwards. The tendencies of (1) and (2) are obviously equal and in opposite directions, and the combination of the two will have no effect.

3. The pressure against the inside of the tube clearly has no effect.

4. Centrifugal force is the only remaining force, and this clearly will cause a difference of pressure on the two sides of the diaphragm of the manometer. Although these two ways of considering the forces which act on the air in the tube are so different they are both correct.

If v = the speed of the aeroplane

r = radius of the circle in which it is flying.

b = the distance between the static heads.

ρ = the density of the air.

P = the differential pressure on the air required to prevent its movement along the air tube.

β = the angle of banking.

With horizontal flight, no side-slip, and the air tube in the vertical plane passing through the centre of the circle

$$P = v^2 \rho b \cos \beta / r$$

Usually β is the correct banking angle, then $\tan \beta = v^2/gr$
In order to make P large b must be large. As the density of the air becomes less with increased height the indications will also become less.

The instrument can only be used for measuring r if we know the speed and the density of the air, but it is not wanted for this, and is only useful for showing that the aeroplane is turning to the right or the left.

If an aeroplane is flying near the ground at 80 miles per hour in a circle of one mile radius, a complete circle would be flown in $4\frac{1}{2}$ minutes, and the correct banking angle would be $4° - 40'$. If the static heads are 30ft. apart the air pressure in the manometer would be about 1mm. head of water when flying near the ground. This pressure will move the hand on the dial through about 14° or about $1\frac{1}{2}$ divisions, and the turn will be clearly shown. If the height of the aeroplane is so great that the density of the air is reduced to half its normal amount the indication will also be reduced to one-half.

The turn indicator has been tried on many different types of aeroplanes. The following are some extracts from a report which we have been kindly allowed to see and quote :—

"In connection with the daily cloud and horizon observations, it has been necessary to attempt to fly through thick layers of cloud. This has been tried on several types of scouts, and after considerable practice it was found possible to get through several thousand feet of solid cloud, but it required very rigid concentration on the control of the machine; even then it frequently got out of control, and after losing height, climbing had to begin again. It was practically impossible to have any sense of direction during a long climb in cloud. Layers

of cloud of various thicknesses up to 6,000ft. were got through, but it was decidedly unpleasant flying."

The turn indicator was then fixed to a 110 h.p. Le Rhône Camel, a difficult scout to fly through clouds. The first position of the static heads was not found satisfactory. A second position was tried. The report goes on :—

" Although not extremely sensitive, it was most useful, enabling the machine to be flown in comfort for a considerable time in clouds. . . . As compared with the experience in clouds on scouts without turn indicators, flying in clouds was now quite pleasant, as the machine never showed any sign of getting out of control. To fly straight was quite easy, keeping a fairly reasonable compass course, to make a gentle spiral up or down, or a very steep spiral. . . .

" The static heads were only tried in two positions, but it may be that a position could be found without their being unreasonably far in front of the plane, so that the indicator would be more sensitive.

" It would need some considerable practice before the average pilot could take a Camel, or most scouts through much cloud, but it makes cloud flying on scouts possible, whereas without turn indicators it is practically impossible."

I have received most kind help in writing the above from Mr. Griffith Brewer, Squadron Leader Stewart, Major Dobson, and Mr. C. C. Mason.

PROCEEDINGS.

FIRST MEETING, 55th SESSION.

The First Meeting of the Fifty-Fifth Session was held in the Hall of the Royal Society of Arts, London, on Wednesday, October 29th, 1919, Brigadier-General R. K. Bagnall-Wild, C.M.G., C.B.E., R.E., presiding.

Major-General R. M. Ruck, C.B., C.M.G., announced that General Bagnall-Wild had been elected Chairman for the year, and he (General Ruck) was sure they were all very pleased this should be so.

The Chairman said he felt almost overwhelmed with the honour of being the Chairman of the Society, and especially so in view of the fact that the Prince of Wales had graciously consented to be their Patron. He (the Chairman) thought this was the first time this fact had been made public; it had already been announced that Lord Weir had accepted the office of President. It was a great honour to the Royal Aëronautical Society to be so situated this year—their first year of activity since the Armistice. It made his (the Chairman's) office an easy one, because with a Patron and a President, the Chairman could always fall back on them for support. On the other hand, he was succeeding their Chairman, General Ruck, who had looked after them, helped them all, and brought them to where they were now after eight and a half years' solid work. He (the Chairman) knew General Ruck when he was a Major and he (the Chairman) was a Second-Lieutenant. General Ruck had inspired him then as he continued to do now. He (the Chairman) had been in close touch with him throughout the whole of his service career and during his career with the Air Ministry. The Society owed a great debt of gratitude to him for all that he had done for them.

He (the Chairman) would like to make one other small point. The Royal Aëronautical Society was going very strong indeed. It might not be known to all present that Glasgow had started a Branch which was promising very well. He (the Chairman) was going down there on November 17th for the Exhibition of Scientific Products in that city, which was bidding very hard to rival London—that was not good enough; they must do more in London.

He had now to announce that Sir Horace Darwin unfortunately was ill and could not read his own Paper. At the last moment he (the Chairman) had asked his old friend, Squadron Leader Wimperis, to read the Paper.

Squadron Leader H. E. Wimperis then read the Lecture.

The Chairman said they had to thank Squadron Leader Wimperis very much for the most able way in which he had read the paper. It was hard to believe he had only had notice just outside the door. He must have read the Paper very carefully or must know the subject well. He thought they would ask him to open the discussion, although this was hardly fair.

The Chairman proposed a vote of thanks to Squadron Leader Wimperis for reading the paper and expressed regret at the absence of Sir Horace Darwin. He thanked General Ruck for his kind remarks and those present for the manner in which they had received them.

DISCUSSION.

Squadron Leader WIMPERIS, in opening the discussion, said he was sorry Sir Horace Darwin could not be present, for more reasons than one, one being that he had invented this excellent instrument which had led to making flying so much easier and more accurate, and the navigation of aircraft so much simpler, that the inventor deserved a public expression of thanks from the Royal Aëronautical Society, and he certainly would have got it with enthusiasm if he had been there. Sir Horace Darwin had described in his Paper the evolution of this static head type of turn indicator. The gyrostatic type was different from his but served the same purpose, and the two instruments, which it was very interesting to compare, could be used more or less indifferently. The principle on which the alternative instrument worked was that if a gyrostat was spinning about one axis and a force was applied to it tending to turn it about a second axis at right angles to the axis of spin, then the gyrostat would endeavour to turn about a third axis at right angles to the two others. The gyrostat, like an Irish pig, declines to be guided by what one wishes, but starts a motion about a third axis, which is as different as it can be from either of the other two axes! That, however, was very convenient for the purposes of an instrument for this present object, because with the little gyrostat spinning on a horizontal axis in direction of travel of the machine, as soon as the aeroplane turned, the gyrostat precessed and so compressed a graduated spring working a pointer over a dial. One had only to gear up its efforts to precess and so compress the spring and thus turn the little pointer through any desired angle. He had flown in a Handley-Page which had both of those instruments fitted, the Darwin type of turn indicator and the gyrostatic type, and it was interesting to perform various manœuvres and to watch the two dials. It was almost uncanny how they seemed to know what was in each other's minds, because they did the same thing—with one qualification, which was rather an important one. That qualification was that the inertia of moving parts in the gyrostat was a great deal less than in the Darwin type of turn indicator, because the mass of air in the pipe, which cannot well be of large diameter, made the Darwin type a little slower in indicating what the machine was doing. The gyrostat was quicker. It was, apparently, in step with what the aeroplane did, and the Darwin type had a slight lag. On a long continued turn they would indicate the same. Sir Horace Darwin referred to some work of Major G. I. Taylor, but he did not mention the recent interesting observations made by that officer, who, whilst in Newfoundland recently, had carried out some sextant observations in the air in order to see how accurately it was possible to determine the position of the machine. The aeroplane was fitted with the Darwin type of turn indicator, and he could make his measurements when the turn indicator was being used to keep the machine flying in a straight course. He told him (Squadron Leader Wimperis) on his return that the accuracy of his navigational observations was materially increased by the use of the turn indicator. He (the speaker) thought that this was one of the most important and promising fields for the use of that instrument. Not only would it improve cloud flying in scouts, but it would greatly assist in getting checks on the position of the machines in long-distance flights. The gyrostatic turn indicator was first invented, he believed, about 1908 by Prof. Henderson, of the Greenwich Naval College, and subsequently—in 1910—was independently invented (the original specification not having been published) by the speaker. Then Sperry, of America, re-invented it, and Major Mendendall, Scientific Attaché of the American Embassy, re-invented it. During the war, Mr. Lanchester, not knowing of any of these previous inventions, also re-invented it. But the original invention was Prof. Henderson's; the credit was due to him, and it should be known by his name.

Mr. DOBSON said he thought everybody would feel extremely sorry Sir Horace Darwin was not there to explain his own instrument, and especially in view of

the cause of his absence. He (Mr. Dobson) could bear out Squadron Leader Wimperis as to the extreme value of the instrument in flying. It had, of course, revolutionised cloud-flying from being a thing of very great difficulty into a thing of comparative ease. A short time ago one of the experimental pilots came down to try the instrument, and he amused himself spinning a B.E.2C. in thick cloud, which is not a thing one would do without the turn indicator. The amazing sensitiveness of the Ogilvie pressure gauge was, as Sir Horace Darwin said, a fundamental part of the instrument. When a machine was banked up all one measured was the difference of the atmospheric pressure at the level of the two static heads. Most people, if they had realised this at the first, would have quailed at the possibility of measuring such a minute pressure, but the Ogilvie gauge did it most satisfactorily. A striking thing was that while one was measuring those minute pressures of a few millimetres one had on top of that the Pitot pressure, which was several inches, to consider. It was striking how accurately the static device gave the real static pressure. After Sir Horace Darwin suggested it, it was put up to Farnborough to develop the idea. It was found when testing various static heads in the wind channel, that no appreciable difference could be found between them, although they were standard heads drawn out of store at random. Fixed static heads fitted on the aeroplanes were found to be extraordinarily good, provided they were absolutely parallel to one another. Squadron Leader Wimperis had raised the question whether the adoption of the swivelling heads was necessary. The swivelling heads were only necessary because one could not be sure of the fixed heads remaining parallel. If they were swivelled they aligned themselves. The other question was that of side slip. When a machine side-slipped there was a difference of static pressure between similar corresponding parts on the right and left wings. One got the same effect whether fixed or swivelling static heads were used.

Mr. G. L. SMITH said Squadron Leader Wimperis had practically saved him the little bit he was to do, by describing the working of the instrument. He (Mr. Smith) showed the actual instrument, as it had been developed at Farnborough. It was extremely simple. The gyrostatic wheel had to be put outside the fuselage of the machine in the wind-stream. The wheel was connected up by vanes to the centre, and those vanes turned it into a windmill. An ordinary speed of 60 m.p.h. gave a speed of something like 9,000 r.p.m. on the instrument. When developing the idea of driving the gyro wheel directly in the wind-stream and doing away with all connecting mechanism they found the slip on the wheel was practically nothing. The speed developed was much more than they wanted. They had since developed another wheel which had a definite amount of slip, because the velocity previously produced was more than the metal could deal with. This wheel was mounted on a shaft passing inside the fuselage of the machine and it could turn on that shaft against two stops. The whole thing was arranged on ball bearings, but at one end it was confined by the spring which Squadron Leader Wimperis had mentioned, and which tended to keep it in a central position in which it remained except in so far as precessional forces altered it. The end of the shaft was connected up to the hand, which showed in a magnified manner any movement of the wheel, and the dial was arranged conveniently for the pilot to see. As soon as the machine started to move the wheel spun up to a high speed and the instrument indicated any slight turn on the dial. A rapid turn gave a large deflection and a slow turn a slight one, so that the movement of the hand showed the rate of the turn. They had not attempted to work it out to make it quantitative in any way. At the zero it would show a very slight turn. A turn which would cause an aeroplane to complete a revolution in say a quarter of an hour, would be quite clearly shown on the dial. But on the other hand, quite a rapid turn was necessary before it passed over to the extreme limit of reading. The control spring had to be altered for different machines. There were three ranges of machines—slow-running, such as Handley-Pages; medium speed, such

as the Bristol Fighters; and the Scout machines with a very high velocity. A machine with high velocity gave high velocity to the gyrator wheel, also the machine with high velocity turned rapidly, and the effects were cumulative. To get over that, they substituted a spring of the requisite strength for a particular machine, and the result was that about proportionate readings were got on any instrument. This was not the only gyro turn indicator. Squadron Leader Wimperis had mentioned several. There were about three in active operation now, one being the electrical one—a beautiful instrument which could be made very small and spun up to a very high speed, and its readings were exceedingly delicate, the only objection being probably the price. There was another instrument spun by compressed air, still another spun by vacuum operated from a Venturi, and then there was this particular one which was blown by the slip stream. They had their advantages and disadvantages. The one he showed had the disadvantage that it spun at a very great speed. Someone in the Air Ministry—he thought a Scotsman—said that it would wear out the bearings and asked if a brake could not be put on it. But how could one be sure the pilot would take the brake off before he entered the clouds. If he did not he would be steering on a good zero, but the aeroplane would be doing what it liked. The bearings, however, would outlast the rest of the instrument.

Mr. OGILVIE said that he did not wish to in any way depreciate the work of others, as in fact, in most cases, he did not know what others had done. From his own point of view the history of the development of these instruments was something as follows :—

The first original side-slip instrument was that of the Wright Bros., which was a piece of string with a frayed end tied at some exposed point on the machine where the pilot could see it. When machines came forward in which the pilot was enclosed, something more elaborate was required.

He (Mr. Ogilvie) first got the idea of his side-slip instrument from Sir Horace Darwin. He was not sure whether it was the 1912 instrument referred to in the Paper, but it was Sir Horace Darwin who first had the original idea of using the difference of pressure on the two sides of a diaphragm to indicate side slip. In Darwin's instrument there was a sort of split pitot tube, in which two tubes were facing forwards at about 45° to the line of flight and the air pressures of the two tubes were taken to the two sides of a metal diaphragm, to the centre of which was attached mechanism with an indicating hand. Anyone would appreciate that with such an arrangement, when the aeroplane travels sideways, one tube would get a bigger pressure than the other; the diaphragm would move and the hand connected to it could be arranged to indicate the direction of the side slip. In his opinion, the mechanism in this instrument was insufficiently sensitive. When he (Mr. Ogilvie) saw that scheme it seemed to him that he could make better use of the idea by connecting the double head to the two sides of his own instrument, which could be made very sensitive to small differences of pressure. That was how his own side-slip instrument originated, and from this instrument was developed a turn indicator.

About June, 1916, when on a visit to the Testing Squadron at Martlesham, where Colonel Tizard was in charge of the experimental work, Colonel Tizard pointed out the difficulty his fellows were experiencing in cloud-flying, or, in fact, in flying a straight course at all, and it was suggested that he should put two pitot heads, one on each wing, and connect to the two sides of a sensitive side-slip instrument. They thought at that time that they had the basis of an idea which would enable pilots to fly in a straight line in a fog, because it was clear that it was quite easy to measure the differences between the speeds at the wing tips of an aeroplane even when the latter was making quite a large turn.

They carried out that experiment, but the results were not altogether satisfactory. He (Mr. Ogilvie) was at that time at the Air Board and busy on the

design programme, and the late Mr. Bertram Cooper, who had been working earlier in the war with the British Wright Co. and knew all about the side-slip instrument, and who was in charge of the Instrument Branch of the Air Board, was pushing him to get on with the scheme. Eventually, Sir Horace Darwin, who was in close touch with the Instrument Branch and who was very much interested in the subject, offered to take the whole job over. Up to that point they were working with pressure tubes on the wing tips, and centrifugal action came in and spoilt the readings, because the side-slip effect overcame the readings one got from the turn. Sir Horace Darwin discarded the positive heads on the wing tips and used the static pressures, and this made a practical success of the instrument.

A reference has been made to the excellence of the static head and the position of the holes. When he (Mr. Ogilvie) became interested in the question of a head for use on his own instrument, Mr. Booth, who had been at the N.P.L., and who was at that time working with him, brought to his attention the N.P.L. pitot tube in which the pressure and the static tubes were concentric with a long taper between the smaller pressure tube and the outer and larger tube, where the static pressures were established. The static holes had to be very far back from the nozzle in order to get the true static reading where there was neither pressure nor suction. This long nozzle made the instrument too fragile for practical aeroplane use, and attempts were therefore made to reduce the length of the nozzle by the use of a stream line end to the outer tube.

A head was made up and sent to the N.P.L., who were asked to drill rings of holes at different distances from the stream line end and test the static pressures in the tube for each position of the holes. The N.P.L. found that the ring of holes could be placed quite near the stream line end without detriment to the accuracy of the static pressure, and this enabled the head to be made both short and strong.

The reason for the sensitiveness of his (Mr. Ogilvie's) air speed indicator was to be found in the fact that in those days he was accustomed to fly at low speeds of 40 m.p.h. or thereabouts, and for that purpose developed instruments to give large readings at low speeds. In fact, he made one for gliding experiments which worked all right at 20 m.p.h. For the diaphragm of the sensitive instruments they used a material called "rubber dam," but when making instruments for 120 m.p.h. machines they used ordinary cycle tube patching material.

Mr. F. P. WALSH said the only observation he had to make was that after hearing a lecture by the late Captain Hucks in June, 1917, he lay awake all that night trying to think of something that would indicate a turn in a cloud.

The result, Letters Patent No. 116375, he put up to the authorities, and, as has happened to many other people similarly situated, it was turned down because, he understood, other means, namely the Static Head Turn Indicator, were then fairly far advanced in development.

Commander W. BRIGGS said they had heard described an instrument which, in itself, was exceedingly simple, but which he was sure would prove of immense value to aeronautics in general.

It was a bold application of known principles carried out in an exceedingly direct and simple manner and should be an example to all of the necessity for careful study of the very smallest details and a standing pattern to those engaged in aeronautics, whose work might seem unimportant and of small compass, of the extreme value it might really possess, when completed.

Major-General R. M. RUCK said he only intended to get up to propose a vote of thanks to the Chairman. He much appreciated the remarks the Chairman made about him, and the way the members accepted them. He (the speaker) had been Chairman of the Society rather over eight years. There had been enormous development, in which he had been extremely interested. He did not think any

credit was particularly due to him, but a great deal of very fine work had been done by the members, collectively and individually. He was sure they had all appreciated the work which had been done by their members in the Field, in the Factories and in the Administrative Offices of the Air Ministry. The Society had done its best to keep up to date, and its success was due to their excellent Council and the good will and work of the Members. There had been a remarkable absence of anything of an unpleasant nature. He was confident they had the makings of a very fine Society, perhaps the most useful form of Society in this country. It was a happy mixture of a scientific society, a technical society, and there were also a certain number of other members who, though not specially scientific, were much interested in the advancement of aeronautics. He sincerely hoped the constitution of the Society would remain as it was at present—of course, with certain improvements, and in that case he believed they had a very great future before them. During the last eight years they had increased ten-fold in membership, and the finances were in a very satisfactory condition. He had felt for some time past that it was not desirable for any Chairman to remain in office so long and had expressed himself to the Council to that effect, so he was only too glad when General Bagnall-Wild was elected as the new Chairman, and was sure that in his hands the immediate future of the Society would be very safe. During the war General Bagnall-Wild had directed a very important organisation, had had great responsibilities, and had been brought into touch with all sides of air work and was thus, he (General Ruck) thought, specially competent for the position of Chairman of the Royal Aëronautical Society. He had great pleasure in proposing a vote of thanks to him for taking the chair.

REVIEWS.

Handbook of Modern Aeronautics. By A. W. Judge. The Library Press, Ltd. 30s. net.

Every subject has its handbook, and it is therefore to be expected that aviation would inevitably be the mother of a further series of compilations. Young as the mother is, however, she has brought forth a handbook of formidable dimensions, sired by A. W. Judge, the well-known aeronautical writer.

All handbooks have certain characteristics in common which spoil them, and Mr. Judge has not had the courage to recognise this fact and to delete these common monstrosities from his "Handbook of Modern Aeronautics." On the first page the reader is informed that twelve inches make a foot and that sixteen ounces go to the pound. If those who compile pocket books for the engineer, whether aeronautical, civil, mechancial, or electrical, would only recognise that this kind of information is not wanted by the majority of engineers they would at once double the value of their pocket books and halve their size. There are tables to convert millimetres into inches, knots into miles per hour, and so on, which no engineer uses, for the simple reason that a slide rule is quicker. Page after page of these tables could very usefully be omitted.

Mr. Judge would have been well advised to wait another few months and to have published in the place of such tables up-to-date information which would have been of more practical use to the aeronautical engineer. His data savours of late 1914. For example, there is no mention of the methods which have been in use for three years among designers for calculating the strength of areoplane spars, taking account of end loads; there are no tables given of the strengths of streamline wires or of tubular struts; while the strut formulæ quoted have been superseded by others during the war which have proved themselves to be nearer the practical truth.

The aerodynamic data throughout are poor. The dimensions of aerofoils and their characteristics are very inadequate and of very little practical use to the modern designer.

It is a great pity that this book has so obviously been rushed for publication, for Mr. Judge runs the risk of spoiling his well-known reputation by leaving out so much which every man who has been in close touch with recent aeronautical design must have in his own private notebook. The book bears evidence of a great amount of labour and it is to be hoped that in a future edition some of this labour will be expended in a more useful direction.

For the elementary stress man and routine designer the book is undoubtedly extremely useful, but for the man who wants the latest information in between two covers it wants much.

J. L. P.

British Airships. By George Whale. John Lane, The Bodley Head. 7s. 6d. net.

This book steers the middle course between the highly technical and the carelessly written popular books which are now pouring out from the presses of England and America on all subjects appertaining to aviation. On the whole the author must be congratulated on having done his work well, and he has produced a book which is not only extremely interesting, but has some claims to be of historical value.

Although very far from being exhaustive from the historical point of view, Major Whale's book contains a well condensed account of the progress of

airships from the early days of balloon flying to the latest rigid airships of the R.33 and R.34 class. In connection with the latter he reveals a war secret which may hurt the pride of the average Englishman. These airships, he points out, were copied as nearly as possible from the L.33 class of Zeppelins, one of which was brought down in September, 1916, in Essex. It rather reflects on the slowness of the Admiralty in adopting rigid airships for the use of the Grand Fleet, but on the other hand the heads of the senior service, once they made the decision to go ahead, did not fail to take advantage of the knowledge to be learnt from the Zeppelins destroyed by our own air forces.

Unlike so many books now being published on aviation "British Airships" has the merit of being as nearly up to date as the exigencies of printing allow. It contains, for example, an account of the historic voyage of the R.34 to America and back. Altogether the book is one worth buying by any airship enthusiast who has not had the opportunity of following the advances in airship construction and work since the early days of 1914.

J. L. P.

A Text Book of Aeronautics. By H. Shaw.

The attempt to deal in one volume with such a wide range of subjects embraced by the term "Aeronautics" is necessarily bound to result in a somewhat sketchy outline. This fault was evident in most of the books published during the war, and the one under review has the same characteristic, although in this case it is not so marked as in the majority.

As a general survey, which we think is what the author intends it to be, it is a very useful book and should have a considerable value in introducing the subject to a student, and indicating to him the large field which is open for study.

The range of subjects touched upon is extremely wide, and chapters upon meteorology, bomb dropping and aerial photography are included, in addition, of course, to the subjects more usually embraced by the term aeronautics.

To deal with all this matter in a book of about two hundred and fifty pages requires considerable selective ability on the part of the author, and one may congratulate Mr. Shaw on his general success in this line. There are, however, parts which might reasonably be omitted to allow for more detailed treatment of subjects not so well understood. As an example, it seems a fair assumption to make that the student approaching aeronautical work will already have a working knowledge of elementary mechanics at least, and the inclusion of a statement of Newton's laws and the ordinary definitions of mechanical science seems to be rather superfluous. If the reader does not already possess this knowledge he had much better leave his reading of any aeronautical work until he has acquired it.

The difficulties of writing a book under the rigid censorship of the war period were very great, and the handicap placed upon the author is evident by some of the omissions. As an example, in the chapter on construction, the designs for built up spars are in no way typical of accepted modern types; and the omission of tables of standard bracing cables is another. The old stranded wire cable standards were superseded a long time before the conclusion of hostilities, by cables made to Air Ministry specification, but these presumably were not allowed to be published.

This lack of completeness was unavoidable under the conditions prevailing when the book was written, but can easily be remedied in a later edition.

In the chapter on seaplanes a strong tendency is shown in favour of the float type as opposed to the boat; one of the principal objections raised to the latter being its aerodynamic faults. As regards performance there is very little to choose between a good boat seaplane and a standard land aeroplane, but the objection raised is that of high engine thrust and a consequent tendency to stall on

cutting out the engine. The high engine thrust is a well known characteristic of boat seaplanes, but there is no difficulty in counteracting the tendency mentioned by careful design and a proper disposition of the tail surface relative to the slip stream from the airscrew, and in all other particulars the boat seaplane is considerably better than the float type. In dealing generally with the problem of high engine thrust at an earlier stage in the book, the author seems to be somewhat confused—the critical term is the distance between the axis of the airscrew and the centre of gravity of the aeroplane. The "centre of resistance" has no significance and is a source of confusion.

The use of standard nomenclature in the next edition would improve the book and render it easier to read.

The work is a useful one and capable of considerable improvement in a later edition by the introduction of matter unavoidably omitted in the present one.

A. J. S. P.

RECENT ADDITIONS TO THE LIBRARY.

"The American Air Service," by Arthur Sweetser. New York, 1919: D. Appleton and Co. Illus. Oct. pp. 384. 10s. 6d.

"British Airships," by Major George Whale. London, 1919: John Lane. Illus. Oct. pp. 244. 7s. 6d.

"Handbook of Modern Aeronautics," by Arthur W. Judge. London, 1919: The Library Press, Ltd. Illus. Oct. pp. 1,005.

"The Thermionic Valve and its Developments in Radio-Telegraphy," by J. A. Fleming. London, 1919: The Wireless Press. Oct. pp. 279. 15s.

"The British King who Tried to Fly," by Howard C. Levis, F.S.A. London, 1919: The Chiswick Press. Illus. Qto. pp. 123. Privately circulated.

"All About Flying," by Gertrude Bacon. London, 1919: Methuen and Co. Illus. Oct. pp. 126. 3s.

"Report on the Progress of Civil Aviation," by Major-General Sir F. H. Sykes. London, 1919: The Air Ministry. Fcp. pp. 9.

"All the World's Aircraft," edited by C. G. Grey. London, 1919: Sampson, Low. Illus. £2 2s. 0d.

"Report on Imperial Air Routes." London, 1919: The Air Ministry.

"Telephony without Wires," by Philip R. Coursey, B.Sc., A.M.I.E.E. London, 1919: The Wireless Press, Ltd. Illus. Oct. pp. 414, 158.

"How to Fly and Instruct on an Avro," by F. Dudley Hobbs. 1919, London: Longmans, Green and Co. Illus. Oct. pp. 75. 3s. 6d.

"Alternating Current Work," by A. Shore, A.M.I.E.E. 1919, London: The Wireless Press. Illus. Oct. pp. 163. 3s. 6d.

"Hydra Tool Steels." 1919, Manchester: Hall and Pickles. Illus. Qto. pp. 46. Gratis.

HILL
REFERENCE
LIBRARY
ST. PAUL